

AMENDMENTS TO THE SPECIFICATION

Please replace the paragraphs [0012], [0013], [0033], [0034], [0035], [0036], [0038], [0039], and [0041] with the following paragraphs rewritten in amendment format:

[0012] The present inventors have calculated the displacement vector on the surface of a doubly-rotated cut quartz blank, i.e., within the plane formed by the X' axis and Z' axis and produced a clockwise in-plane rotation about the Y' Y'' axis such that the X'' axis extends along the direction of displacement vector. A new rectangular blank has been cut so that both sides are parallel to the resulting new X'' axis and Z'' axis, respectively.

[0013] That is, the present invention provides a cut of a piezoelectric resonator comprising a quartz plate made of a quartz having an electric axis lying on an X axis, a mechanical axis lying on a Y axis, and an optic axis lying on a Z axis, the plate having a side parallel to an X' axis established by rotating the X axis in a clockwise direction about the Z axis with an angle of from 3 degrees to 30 degrees to form X' and Y' axes, the quartz plate further having a side parallel to a Z' axis obtained by rotating the Z axis and Y' axis about the X' axis in the clockwise direction with an angle of from 33 degrees to 36 degrees to form the Z' and Y'' axes. This cut of a piezoelectric resonator is characterized in that the quartz plate has sides parallel to X'' axis and Z'' axis, respectively, which have been rotated with angles of from - 35 degrees to - 2 degrees in the clockwise direction about the Y'' axis that is the thickness direction of the cut of the piezoelectric resonator.

[0033] A cut of quartz 12 according to the invention is a cut of quartz having sides parallel to an X'' axis and a Z'' axis obtained by rotating the quartz plate 11 about the $\nabla' Y''$ axis with merely angle Ω as shown in Fig. 2. In this figure, + direction of the $\nabla' Y''$ axis is a direction directed from the rear surface of the paper to the front.

[0034] The present inventors have conducted various discussions on the cut angles of the quartz crystal 10 which have been rotated about the X axis, Z axis, and $\nabla' Y''$ axis and have found that the present cut-angled resonator suffers from less frequency jumps and resistance increases due to spurious modes in various forms than the conventional doubly-rotated resonator. Furthermore, the temperature characteristics are more stable.

[0035] As shown in Fig. 4, the calculated result of the direction of displacement of the main modes on the doubly-rotated cut quartz 11 reveals that the direction of displacement of the main modes is not parallel to the direction of the longer side on the X'' axis but has a deviation angle γ as indicated by the arrow in the figure. Fig. 5 shows the computationally derived results of the direction of displacement of the main modes on the doubly-rotated cut quartz 11 when the rotational angle ϕ about the Z axis is varied. The lateral axis indicates the rotational angle ϕ about the Z axis, while the vertical axis indicates the deviation γ in the direction of displacement. These are represented by defining the clockwise direction relative to the + $\nabla' Y''$ axis as positive (+). As can be seen from the figure, as the rotational angle ϕ increases, the deviation γ

between the $X' X''$ axis and the direction of displacement increases in one direction.

[0036] Accordingly, the blank is rotated about the $Y' Y''$ axis within the plane formed by the X' axis and Z' axis with merely γ such that the direction of the longer sides of the blank becomes parallel to the direction of displacement of the main modes.

[0038] The figures are compared. Fig. 6 shows a case where the direction of displacement is made parallel to the direction of the longer sides of the blank. The rotational angle Ω about the $Y' Y''$ axis is - 8 degrees. Fig. 7 shows a case where Ω is 0, i.e., the direction of the longer sides deviates 8 degrees from the direction of displacement at the doubly-rotated cut angle. Fig. 8 shows a case where Ω is 8 degrees and the direction of the longer sides deviates 16 degrees from the direction of displacement. It can be seen from the comparison of the three figures that the frequency shifts are small and spurious modes are not so strong in Fig. 6 where the direction of displacement is parallel to the direction of the longer sides. However, as can be seen from Figs. 7 and 8, as the deviation from the parallel relation between the direction of displacement and the direction of the longer sides increases, variation width of frequency increases, and the vibration intensity of the whole spurious mode increases.

[0039] After checking these facts computationally, resonators using cuts of quartz according to the present invention were prototyped under conditions of ϕ of 20

degrees and θ of 34.0 degrees. Doubly-rotated cut-angled quartz resonators of this construction were rotated about the Ψ' Y'' axis with angles Ω of - 8 degrees, 0 degrees, and 8 degrees, respectively. The longer and shorter sides of each blank were made parallel to the X'' axis and Z'' axis after rotation within the plane. In the present prototypes, the longer sides were kept constant. Each shorter side was varied by varying the Z side ratio from 15.0 to 17.0, and the frequency of the main modes of each cut resonator was measured.

[0041] The frequency-temperature curves of the cut resonators according to the invention were measured. The results are shown in Fig. 12. A stable frequency of main modes can be obtained over a wide temperature range comparable to the frequency-temperature characteristics of the doubly-rotated resonators shown in Fig. 3. It has been confirmed that rotation about the Ψ' Y'' axis hardly affects the temperature characteristics.